soundest description. He believed the accident had been caused by a lateral blow, such a blow as the tender striking the girder might produce; but it was difficult to say. The breaking of the girder would cause the fall of masonry. Tested the deflection of the bridge before and since the accident, and found it to range from an inch to an inch and three-eighths.

At a further investigation, on Wednesday, a full report of which appears in *The Times*, three witnesses, who had been employed in painting the girders of the bridge, gave evidence that when trains went over it, the deflection was from one inch to *five inches*.

Major-General Sir Charles William Pasley, having been sworn, said:—

I was the Government Inspector-General of Railways when the Chester and Holyhead Railway was opened. I surveyed the bridge over the river Dee on the 20th of October, and reported it as safe. I compared the plans with the actual building, and examined it in such detail as I deemed necessary. It is an iron girder bridge, of three openings or spans of 98 feet each; wrought-iron tension rods are used to strengthen it. I always was of opinion, and am so still, that these tension rods are not of great use, because I consider that the expansion of wrought and cast-iron from heat differs in some degree, although not very greatly; but that iron girders being very massive and the tension bars thin and of small dimensions, the sun may act on the wrought-iron rods very considerably and less on the cast-iron girders; and, supposing them to be adjusted for a moderate temperature, the intensity of hot weather may destroy their proper proportion and do away with the benefit of the tension. I may here state that wrought-iron, when acted upon, will elongate considerably without breaking, but cast-iron will not without breaking. There have been a number of bridges of this description erected on railways in various parts of England, both before and after I held the appointment of Inspector-General of Railways, none of which, with the exception of this one, ever failed. They were not quite of the same extent, but I will allude to a cast-iron girder bridge at York, over the river Ouse, of the York and Scarboro' Railway, which has two openings of 70 feet span. The least depth of the iron girder on that bridge is 3 feet. The least depth of those on the Dee bridge is 3 feet 9 inches; and as the bridge at York and other similar bridges have stood, I concluded that this one would, as it had an extra depth. I may also mention another bridge over the Tees, at Stockton, although I have not seen it. I may vouch for what I state to be correct. It has a span of 83 feet 4 inches, and the least depth of iron is 3 feet.

Mr. R. Stephenson said it was 87 feet.

General Pasley.—I thought it was what I stated, but you may be correct. The flange on this bridge is greater than on others. I have frequently mentioned to engineers that wrought-iron tension rods would do little good. In my inspection of a cast-iron girder bridge, on the Syston and Peterborough Railway, built by Mr. Liddle, the resident engineer, I found that he had omitted tension bars, and in my report to the Earl of Clarendon I approved of the omission, and considered it a preferable construction. It appeared that Mr. Liddle could not get the tension rods in time, and therefore he built the bridge without them. Having mentioned this repeatedly to engineers, and having been given to understand that Mr. Bidder and Mr. Gooch, two gentlemen for whom I entertain much respect, have made experiments with a view of testing the strength of girders without rods, I am informed that the trial was in favour of the latter. As to the cause of the accident;—it has been stated that some time after the Shrewsbury and Chester Railway was opened, and after I had inspected it, a girder was cracked and replaced by a new girder. This circumstance, which I did not know, and which was never reported to Government, coupled with the fracture of this one, induces me to think they are not safe, and that it is the mere cast of a die between their safety and danger. They are on the verge of danger. By examining the bridge on Thursday last and to-day, I consider that the tension rods are of very little use indeed. The tension rods are connected with the girder alone, as if they were part of it. They have no independent support, and there is a difference between this bridge and Mr. Stephenson's former iron girder bridges. In all his former girder bridges there is a connexion from girder to girder, on the central pier or piers, from one end of the bridge to the other, so that when the pressure is on one girder, the other girder in the same line contributes to assist. That is the case with the one on the river Ouse at York. The horizontal portion of these bars appears to be useless. The oblique tension bars would be of use if the upper ends were fixed to some independent support to each pier, and similar independent support on each abutment, and if the standards or support over the abutments had tension bars extending inland to resist the heavy weight going over the extreme bays or openings of the bridge. There is a swing bridge over the river Wensham, at Norwich, strengthened on this principle, and which is extremely judicious. In this case I consider that the girder broke on a train passing over, added to the weight of the ballast that had been thrown on it in the course of the morning. The masonry gave way from the girder breaking, and from that cause alone. I examined the girder; and the castings seemed very good, and I believe it is generally admitted that they are good; but the girder was too weak after the ballast that was put upon it. The girder was far enough in the masonry to support it. There was quite bearing enough to render it secure. I do not think the engine driver suddenly putting on the steam would cause the engine to bound with such force as to break the girder. I saw nothing to throw the carriages off the rails on the bridge, which had strong guard rails. I should say that no girder could have withstood a deflection of 5½ inches, as stated by a witness this day. It would have broken short at once. A continued deflection of four inches must have broken it long before this occurred.

Mr. Robert Stephenson put in a written report on the accident; from which it appeared, that on the day it occurred, and only a few hours previously, he had narrowly inspected every part of the bridge, and saw nothing to indicate weakness. He had carefully examined into every circumstance connected with the disaster since, and for reasons which he gave, was satisfied that it arose from a violent blow against the girder, near to the abutment on the Salteney side, caused by the train getting off the rails. The report said:—

"It has been suggested that the unequal expansion and contraction of the girder, during great changes of temperature, might probably interfere with the uniform strength of the metal. It is impossible to deny that this circumstance does sometimes interfere with the strength of cast-iron beams, but generally this influence may be regarded as confined to castings where the thickness of the different parts vary considerably. In the present case, the form of the castings was carefully studied, and with only such small deviation from absolute uniformity in all the thicknesses of the different parts of the section, as practice has long proved to be justifiable.

With regard to the competent strength of the structure, I concur generally in the deduction drawn by Mr. Yarrow, in which I am confirmed by an extensive experience in the construction and use of similar structures, tried under circumstances that demonstrate their capabilities to meet all the ordinary contingencies of railway traffic."

When the remainder of the evidence is before us, and more accurate details of the construction of the bridge, we shall return to the subject.

At the present moment, when several iron bridges of a very peculiar construction are in progress, when cast-iron girders are being most extensively used, as well in important public and national buildings as in private houses, and a general desire seems apparent to substitute this material for wood wherever it is practicable, it is of the utmost importance that a continued series of experiments upon it should be instituted, and our knowledge of its properties increased.

The difficulty of obtaining uniform texture in castings (on which its strength so much depends), the effect of improper treatment of iron in casting, such as removing it red-hot from the moulds, and the impossibility of judging from external appearance alone, make it imperatively necessary that every cast-iron beam should be subjected to some efficient proof, before it is employed in buildings. To obtain the best *forms* for beams, we need scarcely say, is of the utmost importance, and these are as yet far from determined on.

On a previous occasion we urged the desirability of substituting *wrought* iron for cast, in building, wherever it is possible; as much greater reliance may be placed on the former than on the latter. Exactly two years ago, we reviewed at some length an able report by Sir Henry de la Beche and Mr. Thomas Cubitt, on the fall of the cotton mill at Oldham, wherein the importance of this substitution was forcibly expressed.*

It cannot be other than useful, at this moment, to quote the following passage in that report:—

"While on the subject of cast-iron for beams, we would state our strong conviction, founded on a general view of the subject, of the importance of substituting wrought-iron for cast-iron whenever it can be accomplished, and we anticipate that wrought-iron will be rolled into a sufficient size for all the uses to which large cast-iron beams are now applied, judging from the present size of rolled pieces of iron. When this shall have been accomplished, a great advance will have been made in the use of iron, seeing that beams, or other large pieces of that metal, may, with confidence, be relied upon. We consider that when wrought-iron can be thus rolled and employed, its use will become most extensive, and that the consumption of iron for building purposes would be greatly increased, to the benefit of an important branch of our national industry.

Seeing the increased and increasing employment of cast-iron in buildings in various parts of the country; considering that there is frequent neglect of the form and strength of the cast-iron beams and columns so employed, placing many lives in peril, a neglect not unfrequently arising from an absence of sufficient information on the subject; and regarding extensive knowledge on this head as not only of great importance to your Majesty's corps of Royal Engineers, but also as more likely to be advanced by rendering available the knowledge possessed by that able corps, than by applying to any other body of men in your Majesty's service, we would recommend that, at such times as may be deemed proper, experiments respecting the best and strongest forms of cast and wrought-iron beams and columns should be conducted by officers of the Royal Engineers, at your Majesty's arsenal at Woolwich, or elsewhere, as may be considered expedient, under the control of the Master-General and Board of Ordnance.

We would venture to anticipate that such experiments, so conducted, would be of great public importance, not only by testing the value of those hitherto made, but also by leading to highly beneficial and practical results, the more beneficial in proportion as a knowledge of them could be disseminated by publications of a moderate price, thus spreading the needful information so as to aid those requiring it, and check those who may wilfully neglect, or not be sufficiently thoughtful of the risk of human life."

The hinderance in the way of obtaining wrought-iron beams of sufficient size, is the expense of the works necessary for their production. The demand at this moment is not sufficient to induce individuals to risk the large capital that would be required for such an undertaking; and unless the government lend their aid, it may be a long time before any thing is done in this behalf.

* See Vol. III., p. 277 and p. 288.